Quality Assessment Report:

National Convective Hazard Detection Product

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1. INTRODUCTION

The National Convective Hazard Detection (NCHD) product, created by the Federal Aviation Administration Aviation Weather Research Program's Convective Weather Product Development Team (FAA/AWRP/CW PDT), is being considered for transition from experimental status to National Weather Service (NWS) operations. In support of the decision process, this paper describes the behavior of NCHD relative to its predecessor, the National Convective Weather Detection (NCWD) product.

According to the CW PDT, NCHD was developed to address the known shortcomings of NCWD, primarily the misclassification of some areas of stratiform precipitation as areas of convective hazard (J. Pinto 2006, personal communication). While each product uses the same radar and lightning data as input, the underlying algorithms differ in how they apply processing filters to diagnose hazardous areas. This assessment, lacking a convective hazard "truth" observation, examines NCHD and NCWD in the context of the differences between the algorithms. Quantitative comparison and interpretation for a period during the 2006 convective season are presented along with a qualitative radar case study.

This rest of this report is organized as follows. Section 2 describes the overall assessment approach. Section 3 details the methodology of the intercomparison of the products. The results of the intercomparison and the case study appear in Section 4. Finally, conclusions are presented in Section 5.

2. APPROACH

Without a direct observation upon which an objective comparison could be based, this assessment relies on an intercomparison of NCHD and NCWD to determine which product best diagnoses convective hazard. The CW PDT, intending to better identify and remove stratiform precipitation in NCHD, made significant adjustments to the original detection algorithm, NCWD. Analysis of the results of the intercomparison is based upon these underlying differences. Statistics consistent with the intent of the algorithm changes are interpreted as improvement in the identification of the convective hazard.

The CW PDT presents a comprehensive description of the NCHD algorithm in the National Convective Weather Forecast (NCWF-2) Technical Document for D4 Status (Pinto et al. 2006). The NCWD product is described in Mueller et al. (1999). NCHD and NCWD each use the same input, which consists of National Weather Service (NWS) WSR-88D Level 3 Vertically Integrated Liquid (VIL) and echo top (ET) national radar mosaics along with National Lightning Detection Network (cloud-to-ground lightning information. NCHD pixels are expressed in units of VIL, while those of NCWD are expressed in Video Integrator and Processor (VIP) levels. Table 1 defines the mapping of VIP levels to VIL.

Table 1. Conversion values between VIP and VIL (values adapted from Megenhardt et al. 2004).

VIP Level	NEXRAD VIL ($kg\ m^{-2}$)
1	0.9
2	
3	5
4	10
5	15
6	30

The algorithms share the following two processing elements designed to filter non-hazardous areas out of the combination of the raw VIL and ET data.

a) Echo tops filter: This filter delineates deep convective elements from lesser convection by applying a height threshold to the ET field. Pixels below the threshold are classified as non-convective because they are considered either light precipitation that is not hazardous to aviation, anomalous propagation, or ground clutter (Pinto et al. 2006).

b) Stratiform filter: This filter, based upon the work of Steiner et al. (1995), attempts to partition the observed VIL field into areas of stratiform and convective precipitation. First, the filter identifies all convective centers, which are pixels that exceed a baseline threshold value. All pixels greater than or equal to this value are marked as convective. Next, a search is carried out to find additional pixels that exceed a local average intensity by at least a threshold value, which itself is a function of the background intensity. For each pixel meeting the peakedness criteria, all pixels within a two-pixel distance surrounding the identified location are also marked as convective.

Correspondence with the NCHD developers revealed important differences in the way that these filters are applied to the observed VIL data. Signatures related to each of these changes, described in the list below, should be apparent in the intercomparison statistics.

1. The NCHD algorithm reverses the ordering of the filters, applying the stratiform filter before the echo tops filter. With this change, the CW PDT developers intend to preserve the overall pattern of the VIL field. This allows the stratiform filter to better identify non-hazardous pixels. **This adjustment to the algorithm should manifest as less overall area of convective hazard being reported in NCHD.**
2. The NCHD algorithm increases the convective center intensity threshold of the stratiform filter from the NCWD value of 9.9 kg m^{-2} to 17 kg m^{-2}. The change in equivalent radar reflectivity factor is from approximately 41 dBZ to 50 dBZ. **This adjustment should result in a significant decrease, relative to NCWD, of NCHD pixels with VIL values below 17 kg m^{-2} (VIP levels between 1 and 4) that are reported as convective hazard.**
3. The threshold function (Fig. 1) related to the peakedness criteria of the stratiform filter has been significantly altered for NCHD. The new function, more stringent than that of NCWD, requires a larger difference between the intensity of the pixel of interest and the average

intensity of the background. **The adjustment to NCHD should result in a large decrease, relative to NCWD, of pixels identified as convective. Those pixels with VIL values between 10 kg m^{-2} and 17 kg m^{-2} (VIP levels of 4 and 5) should be particularly affected.**

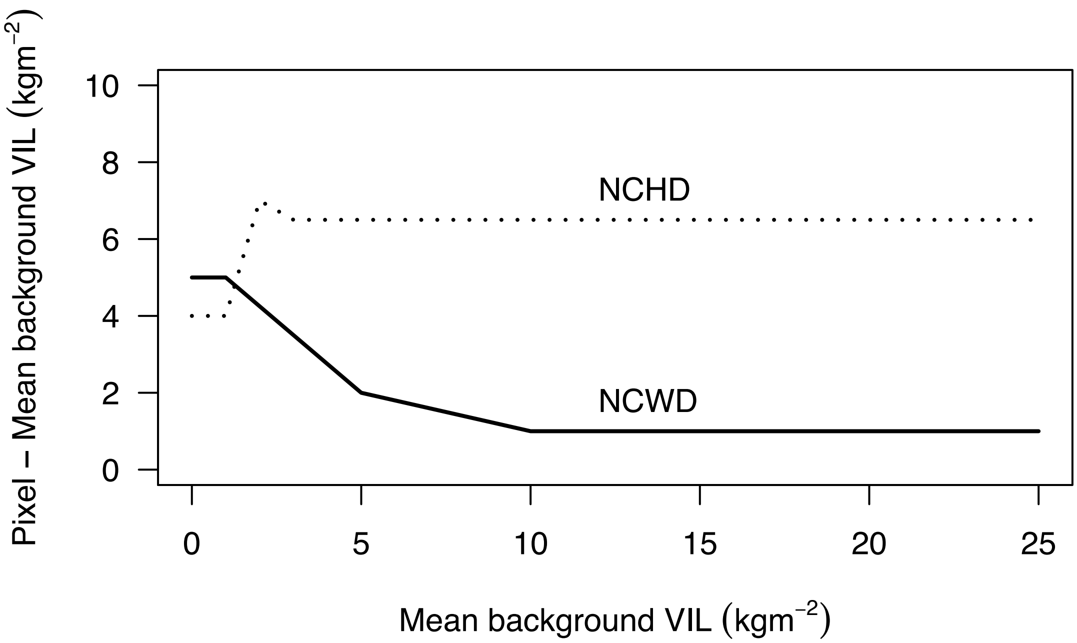

Fig. 1. Functions used for discrimination between convective and stratiform areas for NCHD (solid line) and NCWD (dashed line).

3. METHODOLOGY

This report examines the relative behavior of the NCWD and NCHD products for the period 1 March to 25 June 2006. While each product is generated approximately every five minutes, only grids valid within a time window of plus or minus five minutes of the top of every hour were considered. This yielded a total of 2629 grids of each product for the study. The analysis presumes that the off-hour issuances do not behave differently than those that occur near the hourly boundaries. Due to the different production schedules of NCWD and NCHD, the valid times of the grids in the analysis typically differ by a few minutes. NCHD grids were reprojected, using bilinear interpolation, from their native grid to the grid used by NCWD. Also, the NCHD grid values were transformed from the native VIL values to VIP levels according to the transformation in Table 1. The analysis includes distributions of convective coverage for the products, which are stratified by VIP level. In order to understand the differences between the two products on a grid box by grid box basis, the joint distribution of the two products is also presented.

RESULTS

3.1. Quantitative Comparison

First, the analysis examines average pixel counts per nowcast for each VIP level (Fig. 2). A large difference between the NCHD and NCWD nowcasts is evident for VIP levels 1 and 2, which are typically associated with weak convection or stratiform precipitation. On average, there were more than five times as many pixels with VIP levels 1 and 2 in the NCWD nowcasts than in the NCHD nowcasts. Smaller, but significant, differences are present between NCHD and NCWD at VIP levels 4 and 5. NCHD pixel counts are, on average, approximately 25% less than those of NCWD for these VIP levels. All of the differences observed in this plot seem in line with the intention of the NCHD algorithm developers.

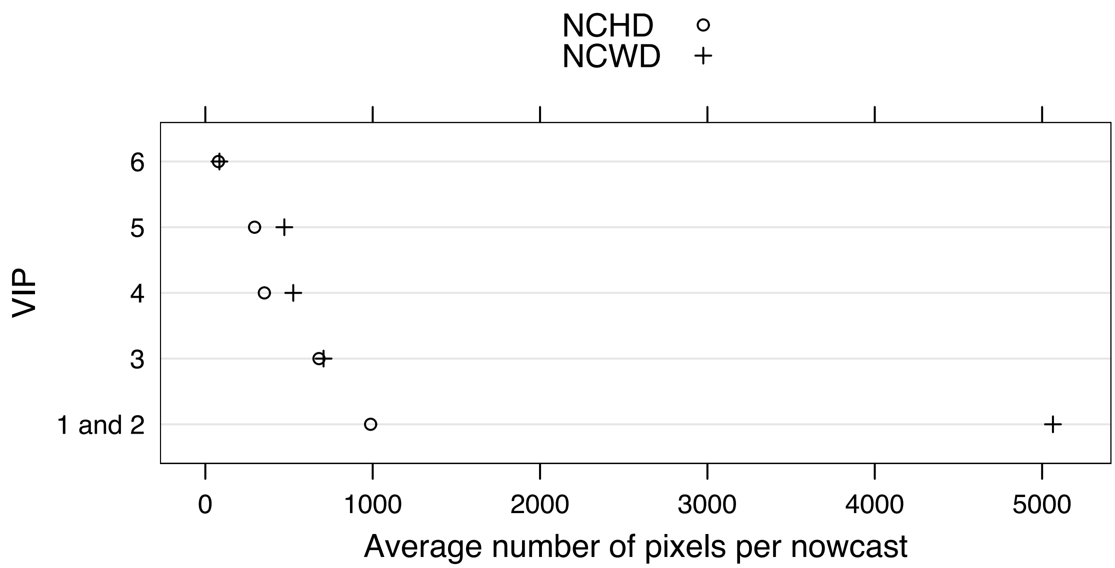

Fig. 2. Average number of pixels of each VIP level for both NCHD and NCWD nowcasts during the evaluation period.

In addition to the average coverage of the individual VIP levels within a nowcast, it is instructive to compare the cumulative coverage of the two nowcasts valid at nearly the same time (Fig. 3). As depicted in Fig. 3, there is general agreement between the two products at most VIP levels except for the combined levels 1 and 2. However, Fig. 3 clearly shows that the coverages of the NCHD nowcasts typically do not exceed the values for their counterparts for all VIP levels. This indicates an overall bias of NCWD towards larger coverages. The bilinear interpolation used to place the NCHD product on the NCWD grid and the slight time differences between the products is likely responsible for the situations where the NCHD coverages exceed those of the NCWD. Again, all of these observations are consistent with the changes made to the algorithm by the CW PDT.

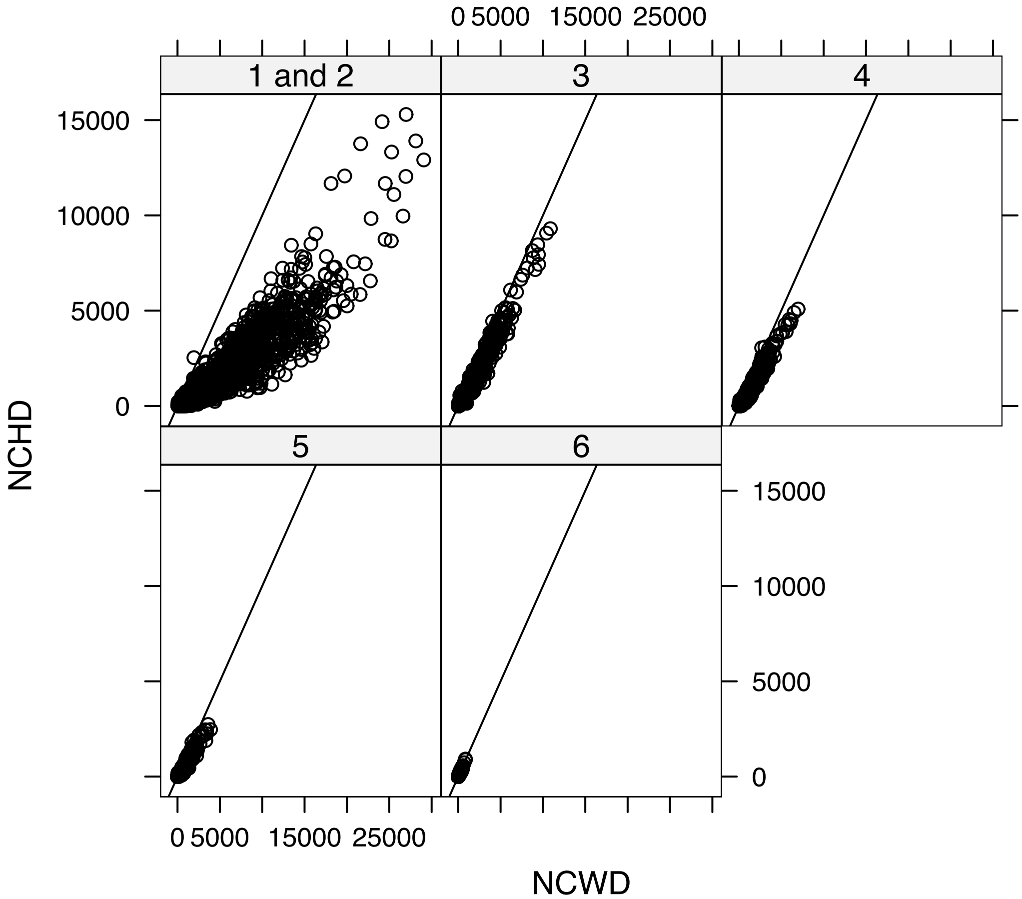

Fig. 3. Scatterplot matrix of the number of pixels meeting or exceeding each VIP level for pairs of NCHD and NCWD nowcasts valid at the same time. Solid line on each panel represents a slope of one.

Finally, the analysis compares the two products categorically in order to assess the degree of correspondence between the pixel counts of each of the VIP levels for each product. The conditional probability of the NCHD VIP value given the NCWD VIP value is shown in Table 2. (The joint distribution of the two products, from which Table 2 was derived, is available in the Appendix.) The improvements made to NCWD to create the NCHD product are clearly evident in Table 2, particularly in the values of the NCHD column of 'None'. In 99.6% of the cases for which the NCWD product indicates a non-hazardous pixel of value 'None', the NCHD value was also 'None'. When NCWD has VIP values of 1 or 2, 91.7% of the time those pixels are associated with no convection in NCHD. This difference lessens as VIL increases but is still clearly evident at VIP level 3, where 43% of the NCWD pixels that indicate hazard are identified as non-convective by NCHD. As expected, agreement between the two products is greatest at the highest VIP levels, which are more strongly indicative of convective hazard. Apparent disagreement of VIP level for hazardous pixels, seen in the non-zero elements of the table not on the bolded diagonal, is most likely an artifact of two issues related to the analysis: the slight difference between the valid times of the products, and the reprojection, which uses bilinear interpolation, of the NCHD data to the NCWD grid.

Table 2. Conditional probability of NCHD given NCWD, p(x=NCHD|f=NCWD). Raw counts used to derive this table are available in the Appendix.

		NCHD					
		None	1 and 2	3	4	5	6
NCWD	None	**0.996**	0.003	8.95e-4	2.55e-4	1.61e-4	1.43e-5
	1 and 2	0.917	**0.055**	0.024	0.005	0.003	3.82e-4
	3	0.425	0.259	**0.206**	0.063	0.041	0.006
	4	0.177	0.202	0.348	**0.171**	0.088	0.014
	5	0.062	0.080	0.187	0.300	**0.308**	0.064
	6	0.014	0.025	0.058	0.119	0.396	**0.387**

3.2. Qualitative Comparison

The results section concludes with a small case study visually illustrating the behavior that has been described thus far for the entire evaluation period. Fig. 4 shows the NWS base reflectivity data from Goodland, KS valid at 2203 UTC on 16 June 2006 along with NCWD and NCHD data valid for the same region at nearly the same time. The NWS image (Fig. 4c) depicts a poorly organized mesoscale convective system (MCS) along the Kansas-Colorado border with a trailing area of uniform, moderate precipitation and strong, leading-edge convection. Additional convective elements are widespread throughout the region and have varying degrees of organization. The NCWD data (Fig. 4a) shows widespread areas of VIP level 1 and 2 echoes, particularly for the trailing region of the MCS. In contrast, the NCHD data (Fig. 4b) has eliminated virtually all of the VIP level 1 and 2 data. The data within this regime is very homogeneous and is being eliminated more effectively by the stratiform filter in the NCHD product. Differences in the VIP level of corresponding pixels are likely due to the valid time difference between the products and the reprojection of the NCHD information.

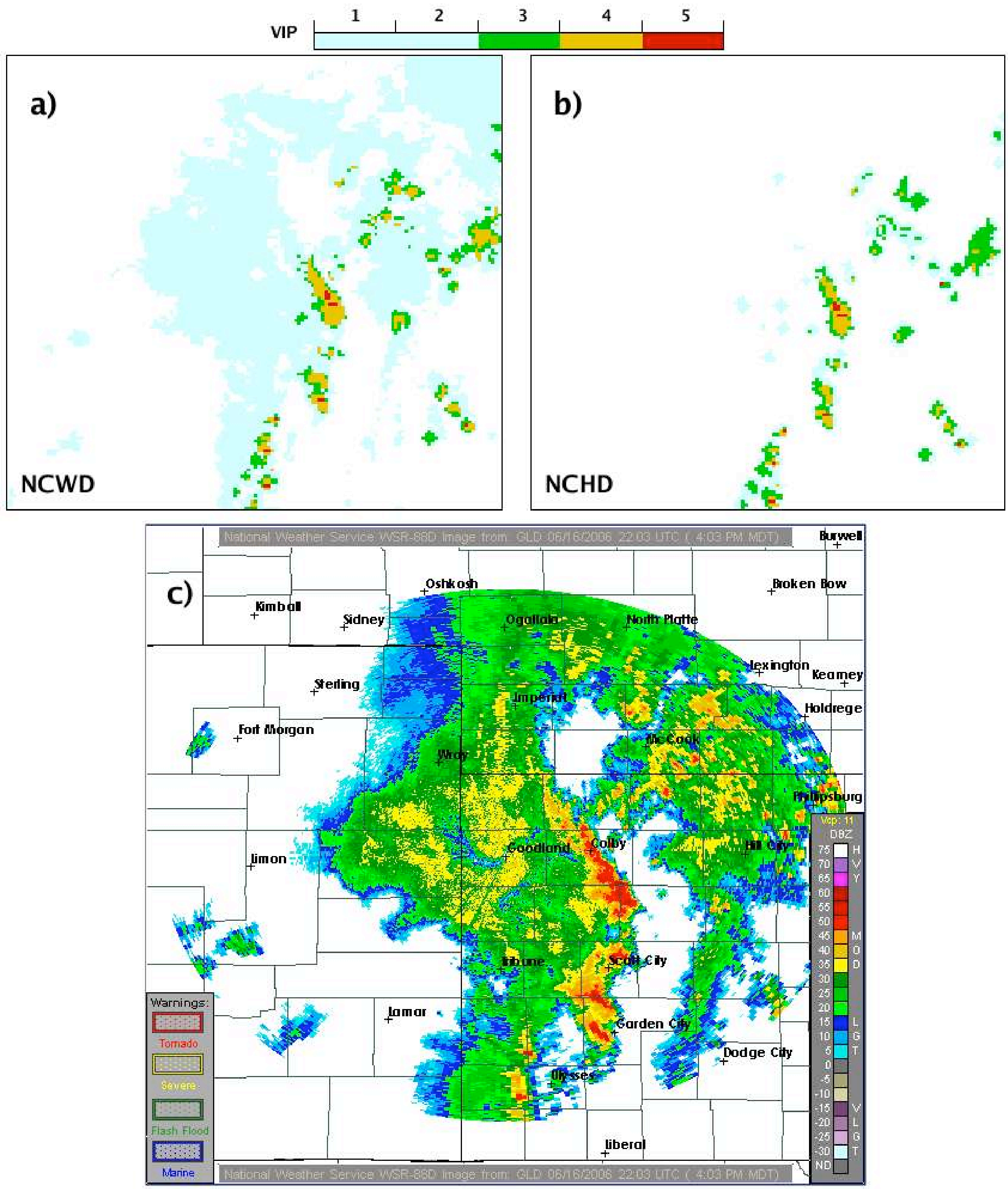

Fig. 4. Comparison of a) NCWD, b) NCHD, and c) NWS radar image from Goodland, KS at 2203 UTC on 16 June 2006. VIP levels 1 and 2 have been combined for the NCWD display to match the VIP levels available in NCHD.

4. CONCLUSIONS

This report compared the experimental NCHD product to the current operational NCWD product. Quantitatively, the behavior of the NCHD product relative to the NCWD product is consistent with the underlying intent of the changes implemented by the CW PDT. The qualitative comparison shows that NCHD depicts areas of hazard better than NCWD for a well-understood meteorological situation. Together, these observations suggest that the improvements made to the NCHD algorithm have had a favorable impact on the identification of convective hazard.

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5. REFERENCES

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APPENDIX

Joint distribution of NCWD and NCHD pixels for the 2629 hours of nowcast pairs available from 1 March to 25 June 2006.

		NCHD						
		None	1 and 2	3	4	5	6	Total
NCWD	None	397021544	997798	356771	101601	64052	5687	398547453
	1 and 2	12138774	735234	320773	72334	42778	5088	13314981
	3	788912	480360	383448	117694	75784	11050	1857248
	4	244405	278540	480026	236367	121646	19757	1380741
	5	77189	98924	231552	372563	381752	78820	1240800
	6	3107	5597	12894	26378	87503	85558	221037
	Total	410273931	2596453	1785464	926937	773515	205960	416562260